MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION

BACTERIA SOURCE TRACKING PILOT STUDY

Summary Report

When your pet goes on the lawn,
Remember it doesn't *just* go on the lawn!

Photo courtesy of Washington State Water Quality Consortium

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Massachusetts Department of Environmental Protection
Division of Watershed Management

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Brief Summary

We now have an effective tool for tracking sources of bacteria in some types of water bodies. Using the Colilert® system, together with field reconnaissance and optical brightener testing, we were able to locate the source of bacteria for dry weather discharges in small subwatersheds. This is a powerful method for finding – then working with towns to eliminate – illicit discharges in smaller streams. This tool is most useful for dry weather investigations rather than wet weather tracking because stormwater runoff produces counts that were usually high everywhere, masking differences between stations and making it difficult to pinpoint specific areas in which to focus tracking efforts. The method also works very well for streams but may not be as effective in lakes and ponds, where in-lake bacteria counts and other indicators of human sewage will likely be more diluted and mixed throughout the waterbody, making it harder to track.

Our field study has demonstrated that this new tool is of potentially great value, both because we have many stream segments with bacteria problems, and because it is cost effective and likely transferable to local watershed protection groups. What we learned from the investigation, and suggestions on how to expand the use of this potentially powerful tool, are set forth in this summary report.

Introduction

Water quality monitoring plans are developed by the DEP/Division of Watershed Management (DWM) to assess surface water quality in support of Clean Water Act, Section 305(b) and 303(d) requirements and therefore, by design, have not usually been very effective in identifying specific sources of pollution that are causing documented water quality impairments. This is particularly true for bacteria contamination of rivers and streams.

In order to address this deficiency, and in recognition of the large number of Massachusetts river segments that are 303(d)-listed due to violations of the water quality standards for pathogens, a pilot bacteria source tracking study was designed and conducted by DWM during the spring, summer and fall of 2004.

The primary goal of this pilot study was to develop a protocol to find sources of bacteria contamination in rivers and streams and field test the protocol on several sites that were in close proximity to the DWM Worcester office and that had documented bacteria problems. A secondary goal was to explore potential pathways for initiating additional source tracking (if necessary) and remediation activities with the responsible party. The study applied and evaluated bacteria source tracking strategies that employed a variety of relatively simple and inexpensive methods including comprehensive landuse characterization of the subwatershed, in-depth field reconnaissance, sampling for bacteria and other indicators of human sewage, and coordination with local and state authorities.

Methods

Three subwatersheds in the Sudbury River Watershed and two subwatersheds in the Blackstone River Watershed were initially selected to pilot the bacteria source tracking protocol. Selections were made based on recent bacteria data that documented water quality impairment due to elevated fecal coliform bacteria in these subwatersheds. Ambient bacteria levels can be highly variable within and between sites, making it often difficult to distinguish patterns, track differences and reach conclusions. In addition, while the potential sources of elevated bacteria levels in surface waters are limited (e.g., pets, wildlife, failing septic systems, illicit sewage discharge, sewer line breaks/infiltration/spills, stormwater runoff, CSO's, agricultural activities), bacteria contamination may be caused by just one or a mixture of these sources within a subwatershed, making source tracking even more complicated. To enhance the ability to interpret the data and better understand how various conditions may influence data variability, the source tracking protocol involved more than just intensive bacteria sampling.

The following source tracking protocol was followed in each subwatershed:

1) Conducted comprehensive subwatershed landuse characterization by utilizing topographic maps, GIS landuse mapping, Stormwater NPDES Phase II municipal storm drainage infrastructure maps (if available), information from local officials and residents, other maps (e.g., local sewer infrastructure) and data (if available), and conducting intensive field reconnaissance;
2) Conducted screening level bacteria sampling for *E. coli* at historical sampling stations and major tributaries and/or pipes within the subwatershed using the Colilert® system to analyze samples in-house for rapid (18 – 24 hour analysis time) turnaround of results during at least two separate dry and wet weather events. (The Colilert® method uses the enzyme substrate test [Standard Methods 9223B] for the detection and enumeration of total coliform, *Escherichia coli* and Enterococci bacteria in surface waters);
3) Conducted source tracking sampling by performing intensive and iterative bacteria sampling during both dry and wet weather events (using in-house Colilert® system) upstream of all contaminated screening level sampling station(s);
4) Further defined source area(s) at stations where elevated counts were found by performing stream walks, Colilert® bacteria sampling above and below suspect landuses, tributaries and pipes, Colilert® bacteria sampling in storm drains (via manholes) with local DPW officials, sampling for optical brighteners (by using a UV light to detect presence of fluorescent whitening agents absorbed on unbleached cotton pads placed in the stream), sampling for fluorescent whitening agents (FWA), measuring conductivity, fluorescence, and/or analyzing for *Bacteroides* for fecal source discrimination.
5) Communicated results to appropriate DEP regional office(s) and municipal officials and coordinated and performed additional sampling to document the problem, as necessary.

Significant Findings

The bacteria source tracking pilot study successfully tracked sources of elevated bacteria at five locations within three separate subwatersheds in the Sudbury and Blackstone watersheds. Two of these sources were found to be from human sewage inputs via illicit discharges to the stormdrain systems, one of the sources was tracked to improper disposal of dog waste into the stormdrain system and two of the sources were likely from concentrated populations of birds and domesticated animals, although further testing using techniques to discriminate between human and non-human sources is needed to confirm this. Summaries of the results and outcomes of source tracking efforts in each of these subwatersheds are presented below. A more detailed description of the source tracking efforts in each watershed is presented in Appendix A.

Blackstone Watershed

Peters River Subwatershed - Source tracking activities revealed three areas in the Peters River subwatershed with consistently elevated *E. coli* counts – upper Arnolds Brook near Pulaski Boulevard, Arnolds Brook at Pine Grove Avenue, and lower Peters River near Wrentham Road.

<u>Results</u>: Elevated bacteria counts in Arnolds Brook near Pulaski Boulevard were attributed to runoff from commercial animal pens containing ducks, geese, chickens, pigs and goats that were located just upstream from the screening level sampling station. Negative optical brightener tests supported this conclusion.

<u>Results</u>: Source tracking activities located a stormwater pipe discharging to Arnolds Brook at Pine Grove Avenue that was contaminated with sewage presumed to be from an illicit discharge to the storm drain system from one or more residences in the upstream unsewered neighborhood. High *E. coli* bacteria numbers, combined with strong positive optical brightener results that confirmed the presence of laundry detergent, indicated that the bacteria were likely from human sewage input(s). Sewage fungus was also observed on the streambed below the stormwater pipe outfall.

<u>Outcome</u>: Frequent communication and cooperation with the Bellingham DPW was required to track the source of laundry water and sewage by intensively sampling the storm drains via manholes and bracketing suspected areas. Bellingham is continuing to survey the storm drain system using a video camera and has narrowed the source to within just a few residences.

<u>Results</u>: In the lower most section of the mainstem Peters River, *E. coli* counts were consistently elevated during both wet and dry weather. Stream walks and optical brightener testing did not indicate obvious potential human sources, however under an upstream bridge crossing, large

numbers of pigeons, pigeon droppings and bird nests were observed. *E. coli* counts measured upstream of the bridge were always lower than downstream of the bridge, so elevated counts in this section of the Peters River were presumed to be, at least in part, from the birds.

Singletary Brook Subwatershed

Results: Source tracking activities did not locate any dry weather sources of bacteria in the tributaries to Lake Singletary. Out of 70 *E. coli* samples collected over the season only 5 were elevated and these were collected during wet weather. Field reconnaissance was conducted in the subwatersheds of the stations with occasional elevated wet weather bacteria counts and no obvious non-point sources were observed, with the exception of evidence of animal activity along the stream (particularly dogs, deer and beavers).

Sudbury Watershed

Baiting Brook Subwatershed - Source tracking activities revealed elevated bacteria counts in two separate areas of Baiting Brook – Belknap Road and Salem End Road.

Results: Elevated bacteria counts in the Belknap Road area were attributed to numerous bags containing dog feces that were found at a storm water outfall to Baiting Brook. The bags were also observed in the contributing storm drain system's catch basins, and were visibly tracked through a residential neighborhood at least three blocks from the outfall.

Outcome: The local (Framingham) NPDES Phase II Stormwater Coordinator and watershed association were notified of the problem in the Belknap Road neighborhood. Storm drain stenciling and other outreach to the neighborhood was encouraged and the DFW Riverways Program stream-team coordinator was contacted to help facilitate a storm drain stenciling project in this neighborhood.

Results: In the Salem End Road area the source of elevated bacteria was never conclusively identified. Although bacteria counts remained high throughout the season, stream walks, FWA and optical brightener sampling did not detect evidence of human sewage inputs. Some of the bacteria may be from a large upstream beaver marsh.

Outcome: More discriminating laboratory methods of human vs. non-human microbial testing are recommended for the Salem End Road area in order to identify the source(s) of the elevated bacteria counts.

Eames Brook Subwatershed

Results: Source tracking activities located a dry weather flow of sewage from a storm water outfall flowing into Eames Brook. Sampling documented *E. coli* and fecal coliform counts in the millions as well as positive optical brightener tests. Sewage fungus was also observed growing on the streambed below the outfall.

Outcome: The Town of Framingham DPW and the DEP Northeast Regional Office (NERO) were notified. Framingham unsuccessfully attempted to correct the problem (believed to be a leaking sewer line overlaying the stormdrain). A model NON for the discharge of pollutants into a stormdrain was drafted by NERO based on this situation. It is expected that the town will correct the problem as a result of this action.

Upper Sudbury River Watershed

Results: Screening level sampling during both dry and wet weather in the mainstem upper Sudbury River did not reveal significantly elevated *E. coli* bacteria counts.

Limited conclusions can be drawn from these results. Bacteria sources may have been present but were sufficiently diluted by the larger volume of water in the Sudbury River, and/or sampling in the main channel of the river may have missed collecting a narrow bacteria "plume" along the shoreline (e.g. sewage-contaminated flow from the stormdrain on Eames Brook was found to hug the shoreline during low flow).

Discussion and Recommendations

Feasibility and Effectiveness

This study demonstrated that the source tracking protocol developed by DWM was a feasible and effective process for tracking and identifying certain sources of bacteria contamination to rivers and streams.

The protocol was most effective in detecting and tracking dry weather bacteria inputs (e.g. illicit discharges) within small subwatersheds. In urban areas (with aging storm and/or waste water infrastructure) source tracking frequently identified human sources of bacteria using a combination of dry weather bacteria sampling and testing for optical brighteners. Several of these sources were tracked to the ends of stormdrain outfall pipes that were inaccessible further upstream. In these cases, coordination with the local DPW and/or stormwater coordinator was needed to help find the source, or if cooperation was not forthcoming from the municipality, enforcement action was necessary.

Bacteria sampling during wet weather produced counts that were usually high everywhere, masking differences between stations and making it difficult to pinpoint specific areas in which to focus tracking efforts. Results from sampling during high flows were also more difficult to interpret due to unknown influences from localized weather patterns, the stream's particular watershed hydrology and stormwater runoff characteristics, and dilution effects of higher flows.

The Colilert® system proved invaluable to the success of the study for several reasons. During the course of the study, over 675 bacteria samples were collected within the two watersheds for in-house analysis with the Colilert® system. Two full time and one seasonal employee conducted the majority of this work. Thirty to forty Colilert® samples could be processed within one hour in the lab. Sample results were available approximately 20 - 30 hours after collection. The advantages of this system allowed us to collect a large number of samples and maintain a flexible sampling plan – important components of the source tracking protocol. Although there is still a 6 hour bacteria sample delivery time and two hour sample analysis time requirement with the Colilert® system, this limitation did not restrict the amount of field work that was performed because the samples were able to be analyzed quickly and conveniently in the DWM laboratory in Worcester. This advantage will make it more feasible to conduct source tracking in more distant watersheds where travel time to deliver the samples to the WES lab puts a limit on the time that can be spent in the field sampling.

The source tracking study required the collection and analysis of a large number of bacteria samples, however, it is important to note that the bacteria data alone was not enough to identify sources. The study demonstrated that a combination of information gathering, field reconnaissance, communication with local residents and town officials, and sampling for bacteria and optical brightener testing was most effective in finding sources. Other methods to distinguish between human and non-human sources (e.g., sampling for WES analysis of fluorescent whitening agents and *Bacteriodes*, and measuring specific conductance and fluorescence) were also used in the study, but more work is needed to evaluate the effectiveness of these methods.

The source tracking protocol piloted by this study was developed for rivers and streams. If bacteria source tracking work is proposed for lentic systems some modification to the strategies used in this study will be necessary and will need to be field tested. The methods used in this study can be used for tracking bacteria inputs to lakes that are entering from flowing pipes and tributaries, however in-lake bacteria source tracking will require different tools currently not available to DWM (such as dye testing and infrared imagery).

Effective tools and methodologies for tracking certain sources of bacteria impairments to rivers and streams are now available at DEP. Based on the positive results of the study, it is recommended that bacteria source tracking be considered for selected subwatersheds in conjunction with DWM's regular water quality assessment monitoring. Addressing impairments by identifying the source(s) and recommending (and in some cases initiating) specific actions for remediation should reduce the efforts required later as part of the TMDL process. In cases where the source of contamination is quickly remediated, the water quality impairment - and resultant TMDL requirement - will be eliminated.

Recommendations for conducting future source tracking surveys

Planning:

- Incorporation of bacteria source tracking work into DWM monitoring plans for year two watersheds (Deerfield, Millers, Buzzards Bay, Merimack and Shawsheen) may be useful for certain stream segments currently impaired for bacteria (Category 5 of Integrated List). Bacteria source tracking work should be developed in consideration of available resources and with other DWM water quality monitoring objectives for these watersheds.
- If bacteria source tracking is incorporated into the year-two DWM monitoring plans, priority should be given to small (< 10 square miles) urban or suburban subwatersheds draining to segments that have historically exhibited consistently high bacteria counts during dry weather conditions. When prioritizing sites for source tracking, the proximity of public uses to the waterbody such as water-based recreation, drinking water supplies, and accessibility of the area to the public should be considered. Results of the initial screening level bacteria sampling in these segments will identify specific locations where bacteria contamination is still occurring and the number of subwatersheds where source tracking work may be useful.
- Formation of a source tracking advisory group (4 – 6 people) at the beginning of the project is recommended to advise survey coordinators on all aspects of the study, including prioritizing subwatersheds for study, survey design, and to help interpret results and plan the next tracking activity.
- A flexible sampling plan is recommended. Weather is an important factor to consider when planning surveys and may call for sampling on short notice.
- Before data collection begins, data managers and source tracking group should establish how the data will be managed and reported.
- Characterize landuse and conduct field reconnaissance early in survey planning process.
- Establish communications with local DPW, Boards of Health, Phase II Stormwater coordinators, etc., early in the information gathering phase. Use local knowledge, infrastructure maps (historic and recent), and Phase II Stormwater information to help plan surveys.
- From this study, it appears tracking efforts are most effective within small subwatersheds of first or second order streams (less than 15 square miles). Mainstem rivers appear too large to track – need to address mainstem problems by tracking in subwatershed tributaries. Found that small illicit discharges may hug banks and otherwise not mix with streamflow even in small streams.
- Lakes and estuaries may require a different source tracking approach than river systems. If in-lake and/or estuarine source tracking is to be conducted, modifications to the study approach will be needed to address different hydrologic characteristics (i.e., lentic vs. lotic).

Implementation:

- Using Colilert® allowed DWM to maintain a flexible sampling plan, increase the number of bacteria samples collected, and provided reliable results within approximately one day of collection.
- Bacteria results were extremely variable and very dependent on precipitation and flow, however the results that were most conclusive and helpful in isolating specific sources were collected during dry weather. Stormwater sampling was helpful for screening level sampling, but not for source tracking because bacteria in stormwater was usually high everywhere.
- Often sources were tracked to underground pipes/stormdrains – these problems will require coordination with the municipality (e.g., DPW) to track further.
- A combination of field sampling techniques is most effective to source track (e.g., iterative bacteria testing, optical brightener testing, and field observations).
- Using these methods, source tracking in multiple (5 – 7) subwatersheds in a sampling season is possible with a minimum of 2 coordinators and one seasonal employee.
- Fluorometer analysis to help discern human vs. non-human sources in fresh water was inconclusive in this study – more work is needed to fine-tune this method before it can be used as a reliable source tracking tool.
- Fluorescent whitening agent (FWA) sampling was inconclusive in this study – the method needs more field-testing for use as a bacteria source tracking tool.
- *Bacteroides* sampling to help discern human vs. non-human sources was not useful in this study – the method is currently being validated at WES.

- Ultimately, bacteria sources to some areas will not be identified without the use of more sophisticated methods to discriminate between human vs. non-human sources and between animals (e.g., DNA type testing).

Follow-up:

- Establish and maintain close communication with municipal officials and appropriate regional office(s) of DEP. This connection facilitates remediation activities if problems are found.
- Cooperation from municipalities will differ. Work together with cooperative municipalities to find the source and use enforcement action to stimulate less cooperative communities to take action.
- Working closely with the appropriate regional office(s) of DEP, establish a procedure for follow-up and remediation when sources are found.
- Explore the possibility of establishing a dedicated revenue source for communities to access to help defray the cost of remediation which may range from specialized testing to pinpoint the source of bacteria (such as dye testing and/or remote video camera work in storm drain systems) to extensive infrastructure repairs.

APPENDIX A

Subwatershed Source Tracking Summary Reports

List of Figures

Peters River Subwatershed

Subwatershed Description:

- 7.1-mile tributary to the Blackstone River in (Bellingham, MA to Woonsocket, RI)
- 12 square mile subwatershed
- Top 3 land uses: Forest, Residential, and Agricultural
- 83 percent of Bellingham relies on on-site wastewater treatment and disposal systems
- Dense residences and businesses in south Bellingham comprise the most urban area in the Town - storm drains cover most of the area, and many outfall directly to the Peters River
- Bellingham, Franklin, and Wrentham are Phase II Stormwater communities
- Peters River is listed on the 2004 Integrated List Category 5 for metals and pathogens

Sampling Summary:

- 10 initial core stations for screening in the Peters River Subwatershed
- 38 stations were sampled by the end of the season (April – September)
- 17 sampling events in the Peters River Subwatershed

Results and Source Identification Summary:

- *Arnolds Brook downstream from commercial animal pens – Figure 1. Pulaski Boulevard*
  In the upper portion of Arnolds Brook, six sampling events occurred downstream from an animal pen property. Elevated E. coli bacteria counts were noted regardless of wet or dry weather. Bacteriodes samples were collected at this location to confirm non-human source of E. coli bacteria due to upstream concentrated animal lot. These results have not been reported to DWM.
- *Stormwater outfall to Arnolds Brook – Figure 2. Lowland Street neighborhood*
  In the lower portion of Arnolds Brook a stormwater outfall enters the stream upstream of its confluence with the Peters River. Samples were collected from this stormwater outfall on 12 occasions, half of which came back with elevated E.coli counts. Optical brightener (OB) pads were deployed at this location to determine the presence of fluorescent whitening agents (FWAs) – source from laundry detergents. A strong positive was observed from the OB pads collected at the outfall. DWM worked with the Bellingham Department of Public Works (DPW) to track the infiltration of laundry water to the storm sewer system in this area. Three rounds of storm sewer manhole sampling occurred to track the possible presence of illicit connections and/or failing septic systems. Nine manholes were sampled and one showed the presence of soapsuds and elevated E.coli bacteria counts. The DPW is continuing to track this storm sewer line with the use of a video camera – conclusion pending. The Public Health Department was also contacted regarding the status of septic systems in the area.
- *Lower Watershed of Peters River – Figure 3. Wrentham Road*
  The most downstream sampling station on Peters River (sampled 14 times) showed consistent elevated E.coli bacteria counts regardless of wet or dry weather. 100 meters upstream of this sample location is a road crossing – samples were collected upstream and downstream of this road crossing on four occasions. On all occasions, samples collected downstream of the road crossing were higher than samples collected upstream. Upon further investigation, under the road crossing were gross amounts of pigeons, pigeon nests, and pigeon droppings. Bacteriodes samples were collected at this location to confirm non-human source of E. coli bacteria. These results have not been reported to DWM.

Figure 1. Pulaski Boulevard - Commercial animal pens adjacent to Arnolds Brook.

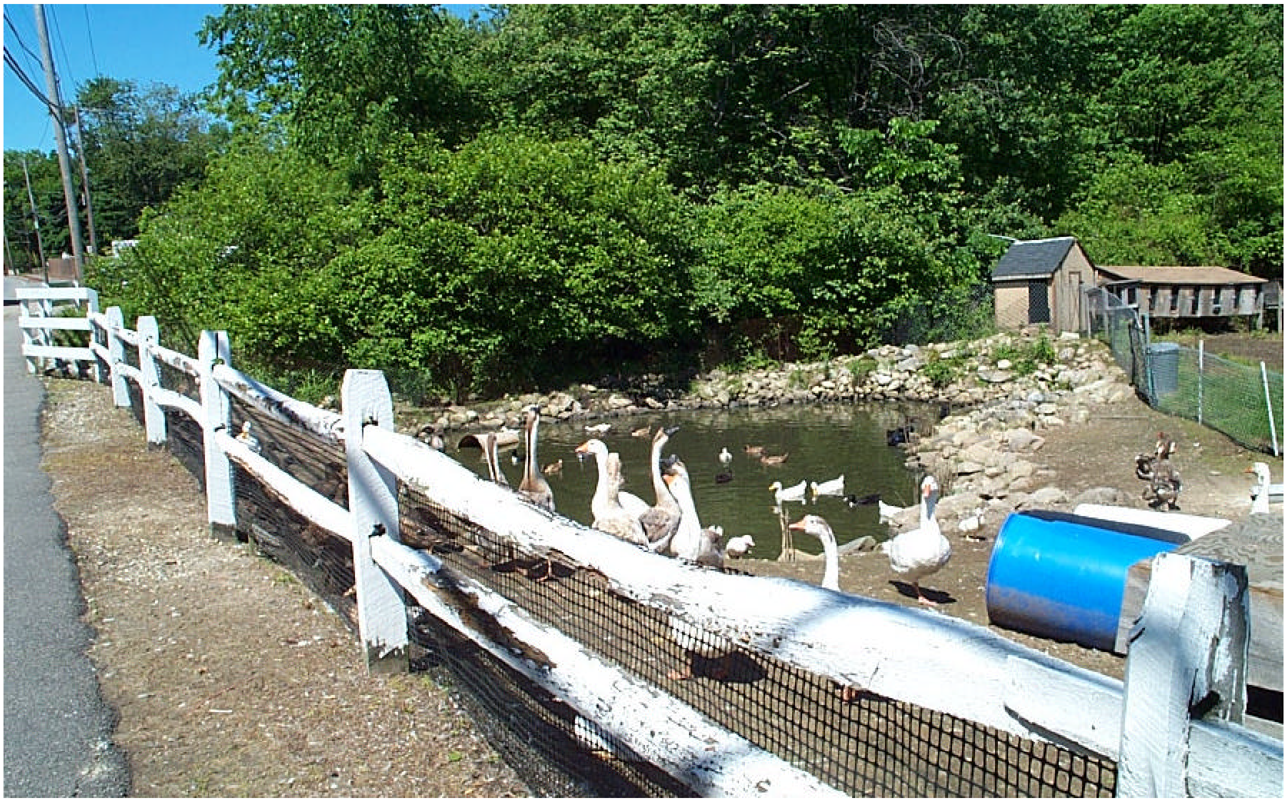
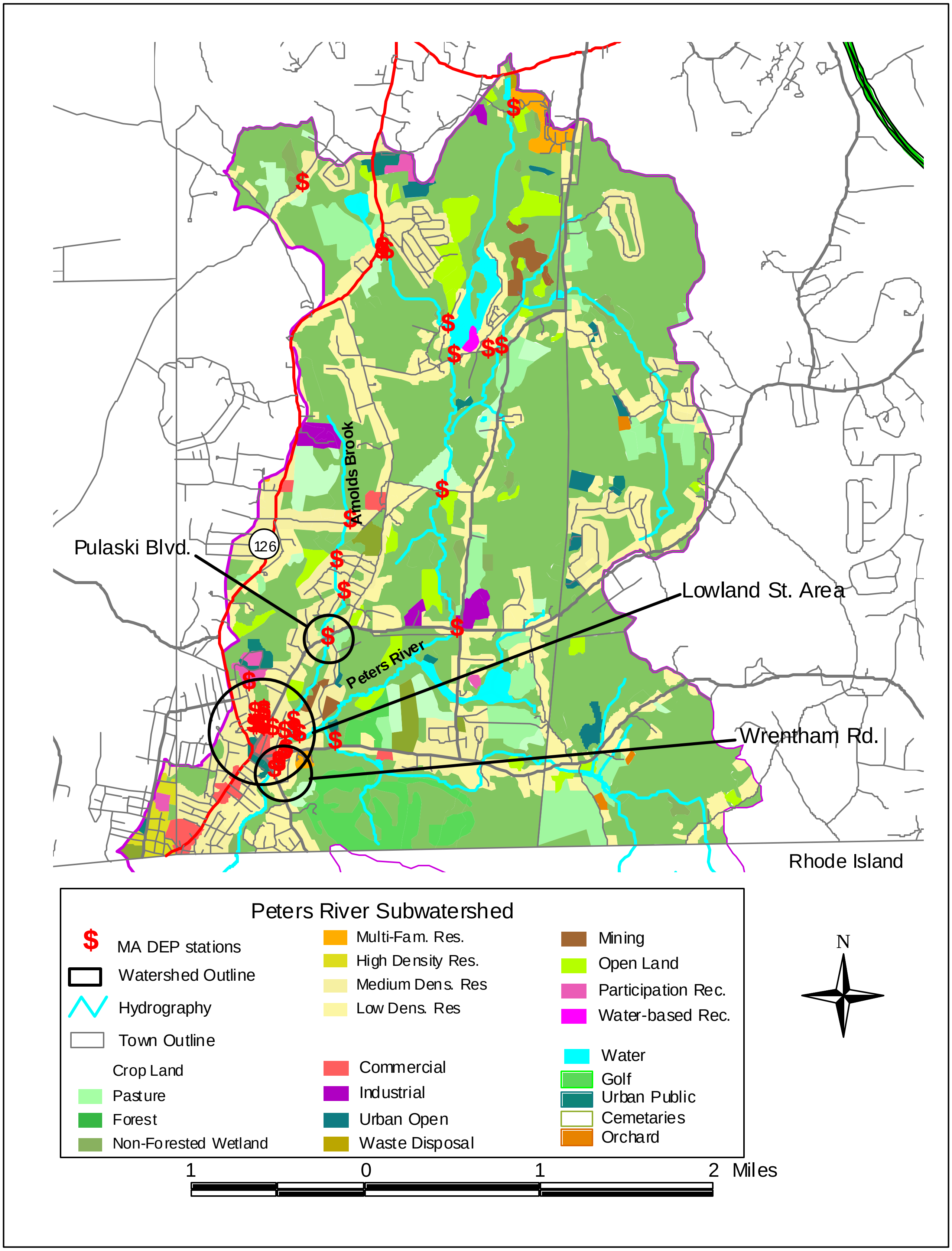


Figure 2. Lowland Street manhole - storm sewer system to Arnolds Brook - soapsuds.

Figure 3. Wrentham Road – bird droppings.

Figure 4. Source Map for the Peters River Subwatershed.



Singletary Brook Subwatershed

Subwatershed Description:

- 6 square mile subwatershed
- Top 3 land uses: Forest, Residential, and Agricultural
- Lake Singletary is located in the northern part of Sutton and its border extends into the Town of Millbury. The small lot sizes, steep slopes, and poor soil types found in the developed areas along the northwest and eastern shoreline have created concern in regards to pollution of Lake Singletary from septic system failures.
- Millbury and Sutton are Phase II Stormwater communities

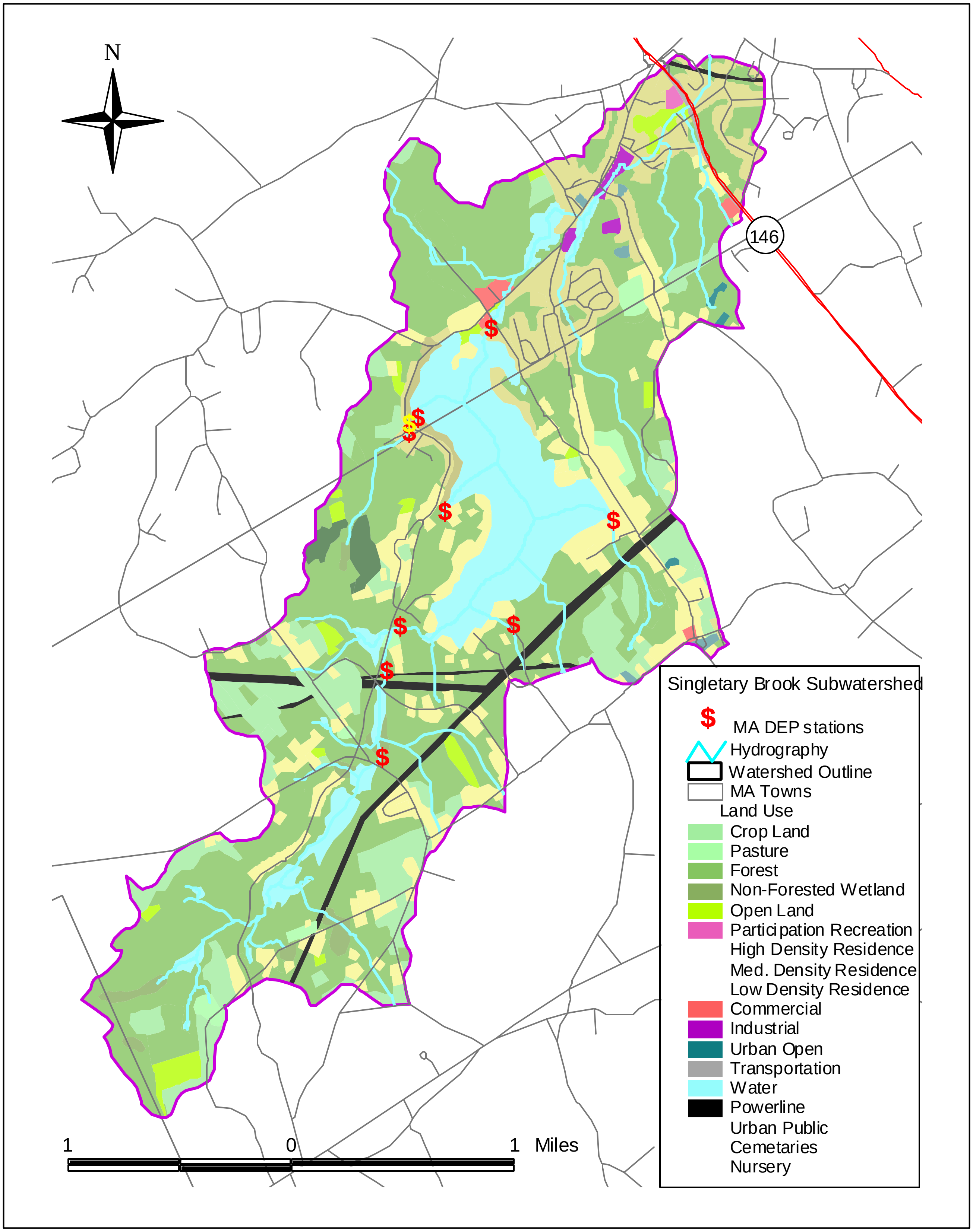
Sampling Summary:

- 8 initial core stations for screening in the Peters River Subwatershed
- 10 stations were sampled by the end of the season (April – August)
- 9 sampling events in the Singletary Brook Subwatershed

Results and Source Identification Summary:

- *Singletary Brook Subwatershed*
  There were only five elevated E. coli bacteria counts out of 70 samples collected in this subwatershed. In July and August, the majority of the samples stations were beginning to lose flow and some stations were not sampled on a few occasions.

Figure 5. Map of Singletary Brook Sample Locations.



Baiting Brook Subwatershed

Subwatershed description (Figure 6):

- 4.7-mile tributary to the Sudbury River in Framingham, MA
- 3.4 square mile subwatershed
- Top 3 land uses: Forest, Residential and Agriculture
- Homes in the headwaters are on septic systems; the remaining portion of the Baiting Brook subwatershed is sewered.
- Impervious cover for upper two-thirds of the subwatershed is only 3% vs. the highly-developed lower one-third at 16%
- 48 storm water outfalls in the Baiting Brook subwatershed were identified by the Town of Framingham in the application for their NPDES Phase II storm water permit.

Sampling summary:

- 8 initial core stations in the Baiting Brook subwatershed.
- 30 stations were sampled by the end of the season.
- 14 sampling events in the Baiting Brook subwatershed.

Results and Source Identification Summary:

- **Callahan State Park**
  Elevated E. coli counts due to precipitation were more apparent in the lower subwatershed where there is a significant increase in impervious cover. However, sampling during a significant rainstorm would show elevated counts downstream from the agricultural areas and Callahan State Park, a popular dog walking and horse riding park in the upper subwatershed. Wildlife in the forested areas are also a contributing source.

- **Belknap Road (Figures 7, 8 and 9)**
  In a neighborhood downstream from Callahan State Park numerous bags containing dog feces were found at a storm water outfall to Baiting Brook. Bags were traced through the storm drain system at least 3 blocks away. The bags originate from the neighborhood and not from the park. On one occasion 18 bags were retrieved from the storm water outfall for proper disposal. One month later approximately 40 bags caught in-stream and on the stream banks were picked up for proper disposal by DEP during a stream walk of one block.

- **Route 9 and Salem End Road**
  E. coli counts became consistently elevated from Route 9 in Framingham down to the confluence with the Sudbury River at the end of May when flow in the brook began to decrease. Wildlife is a contributing source upstream from Route 9, but final source identification in the lower Baiting Brook subwatershed is pending Bacteroides results from DEP's Wall Experiment Station.

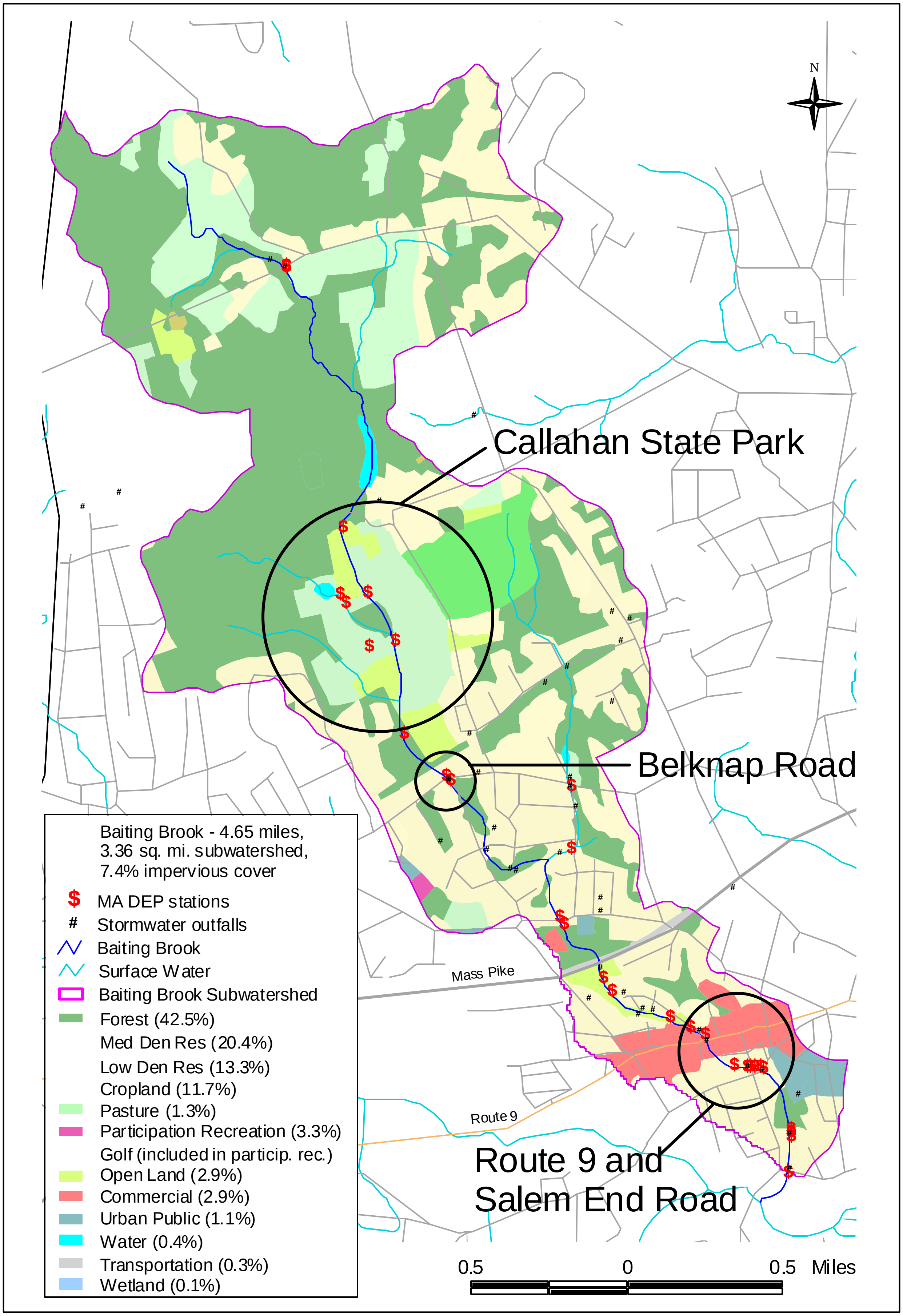
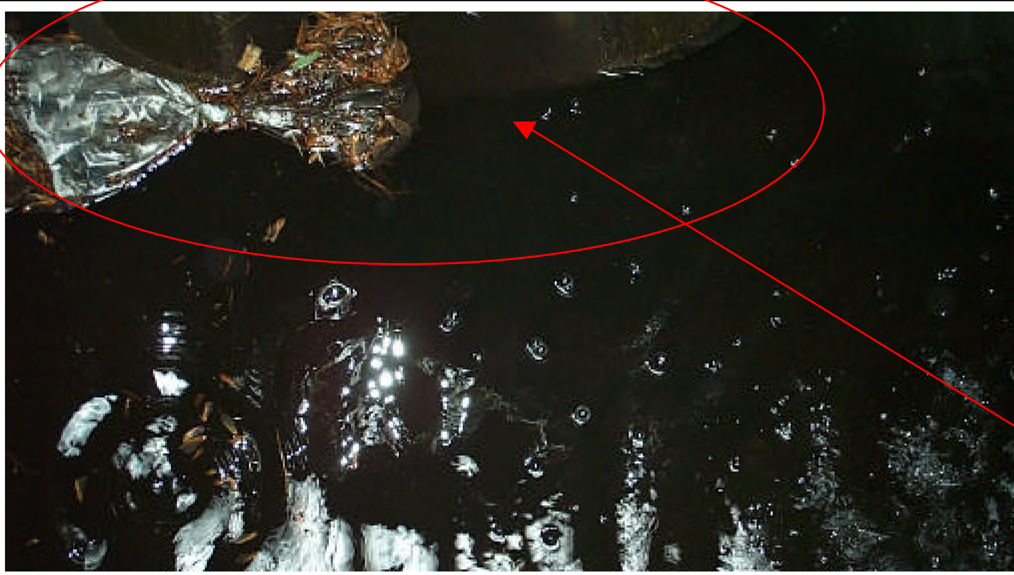


Figure 6. Baiting Brook subwatershed land use and sample station locations.

Figure 7. Bags of dog feces at outfall on bank of Baiting Brook.



Bag in catch basin entering top of outfall.

Figure 8. Dog bag entering top of outfall (looking down into catch basin).

Figure 9. Dog bags collected from brook and on banks during 1 block stream walk.

Eames Brook Subwatershed

Subwatershed description (Figure 11):

- 0.5-mile tributary to the Sudbury River in Framingham, MA
- 1.2 square mile subwatershed
- Top 3 land uses: Open Land, Residential and Commercial
- The 140 acre Farm Pond and 31 acre Learned Pond make up approximately 16% of the Eames Brook subwatershed.
- The entire Eames Brook subwatershed is sewered.
- Impervious cover of the subwatershed is estimated at 27%.
- Approximately 19 storm water outfalls in the Eames Brook subwatershed were identified by the Town of Framingham in their application for their NPDES Phase II storm water permit.

Sampling summary:

- 5 initial core stations in the Eames Brook subwatershed.
- 15 stations were sampled by the end of the season.
- 10 sampling events in the Eames Brook subwatershed.

Results and Source Identification Summary:

- **Mt. Wayte Avenue**
  On the 6^{th} sampling event at Mt. Wayte Avenue, closer examination of a storm water outfall revealed a dry weather discharge of raw sewage coming from a break in the outfall approximately 1 foot inside of the pipe (Figure 10). E. coli counts of the discharge were estimated at 2.9 million cfu/100ml. Sampling downstream from this outfall was discontinued, as it would not be possible to distinguish a 2^{nd} source from this direct contamination.

Figure 10. Dry weather discharge to Eames Brook at Mt. Wayte Ave, Framingham.

- **Unnamed tributary to Eames Brook**
  Elevated E. coli concentrations were noted later in the sampling season and attributed to wildlife and low flow conditions.

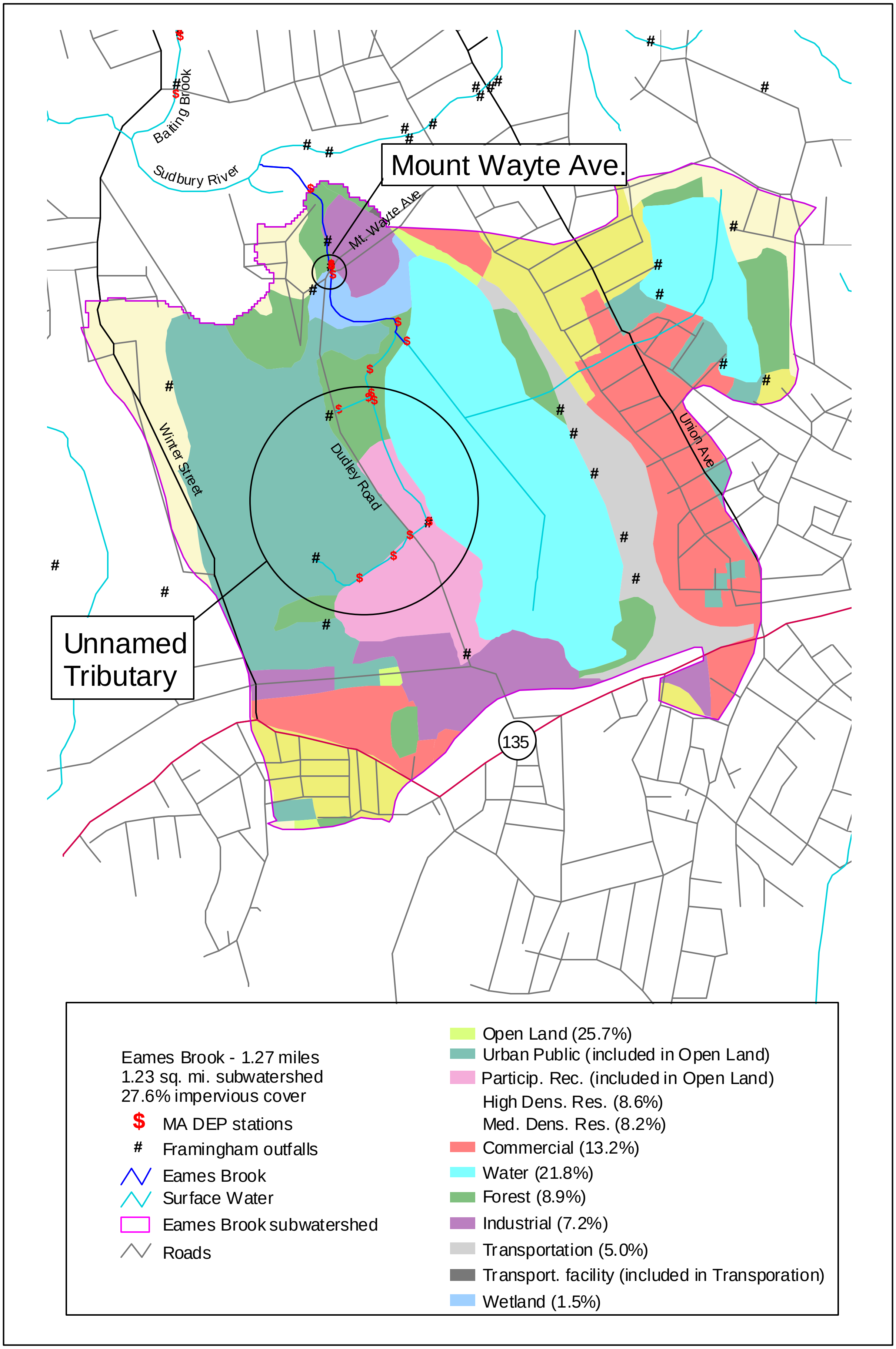


Figure 11. Eames Brook subwatershed land use and sample station locations.

Upper 4 Miles of the Sudbury River

Subwatershed description (Figure 12):

- 4 mile length of the Sudbury River from the headwaters out of Cedar Swamp, Westborough through Southborough and Hopkinton to Cordaville Road, Ashland.
- 33 square mile subwatershed
- Land use is mostly forest and residential with light commercial use.
- Mix of septic systems and sewers for wastewater disposal.
- An impervious surface analysis of the subwatershed for this portion of the Sudbury River shows that even when limiting the analysis to a 500-meter riparian zone buffer of the most developed reach of the river; the impervious surface is less than 10%.

Sampling summary:

- 5 initial core stations in the Sudbury River.
- 7 stations were sampled by the end of the season.
- 5 sampling events on the Sudbury River.

Results and Source Identification Summary:

- **Sudbury River**
  Dry and wet weather E. coli concentrations were below proposed standards for all stations on the Sudbury River with the exception of 2 dates at 1 station where the results were less than 20 mpn/100ml above the DPH bathing beach standard of 235 cfu/100ml.

- **Cedar Street, Hopkinton/Southborough**
  A continuous flowing storm water outfall (most likely a diverted underground tributary or groundwater spring) mixed with storm water at Cedar Street in Hopkinton/Southborough, had slightly elevated E. coli counts (700 and 548 mpn/100ml). Minimal source tracking took place at this outfall due to the fact that the infrastructure is completely underground, is diverted underneath active railroad tracks and because the elevated concentrations were considered too low to track and were not impacting the mainstem river.

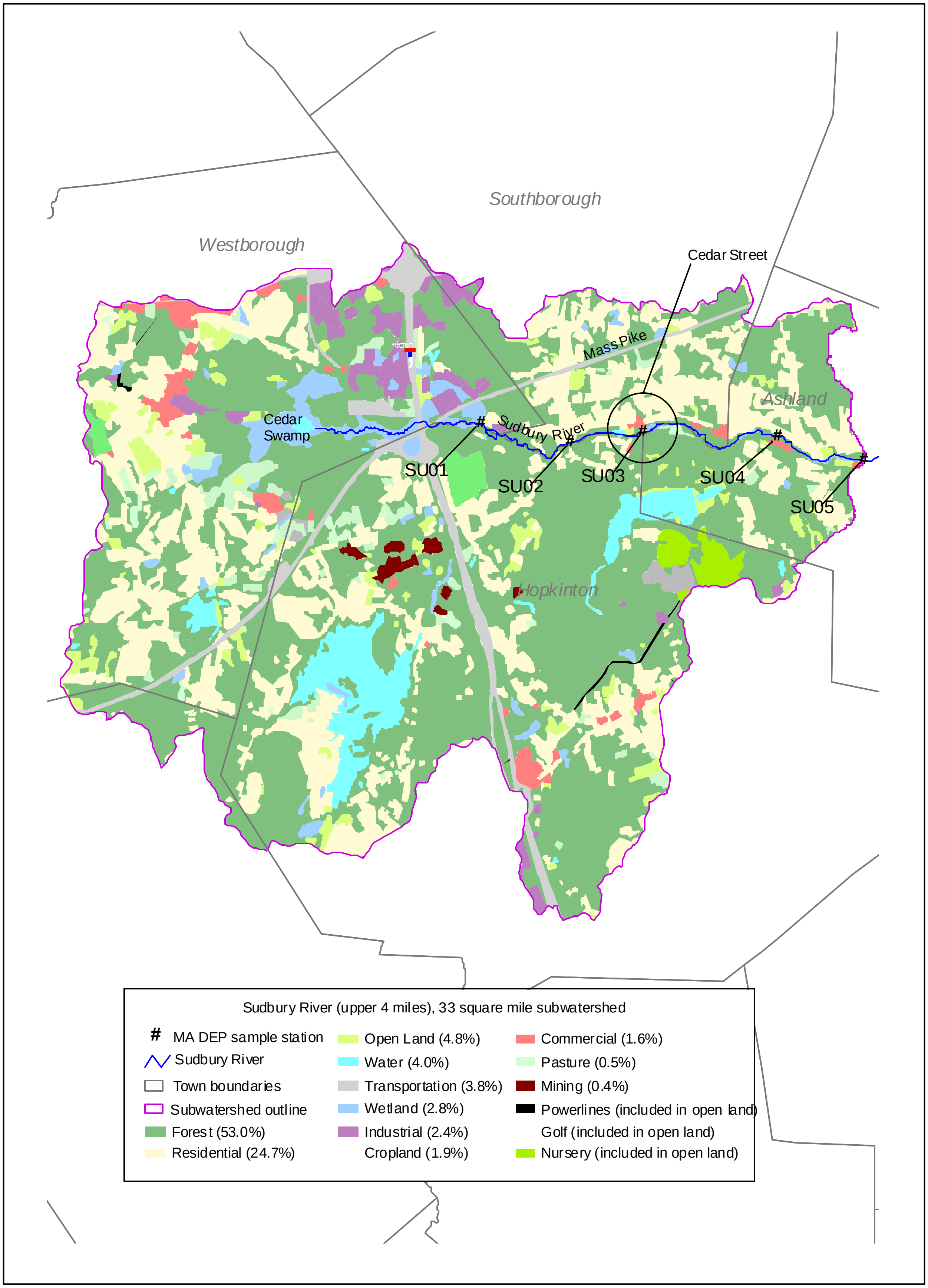


Figure 12. Upper Sudbury River subwatershed land use and sample station locations.